UNIVERSITÉ DE MONTRÉAL

CENTRE DE RECHERCHE SUR LES TRANSPORTS

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INTERACTIVE-GRAPHIC AND OPERATIONS RESEARCH METHODOLOGIES FOR FREIGHT DISTRIBUTION AND TRANSPORTATION SYSTEMS PLANNING

by

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This research has been partially financed by the programme "coopération France-Québec" under Project Number 20020686FQ.

Paper presented at IFORS '87, Buenos Aires, Argentina, August 1987.

Cette étude a été publiée grâce à une subvention du fonds F.C.A.R. pour l'aide et le soutien à la recherche.

Université de Montréal
Centre de recherche sur les transports - Publication #560
August 1987

Dépôt légal - 1er trimestre 1988

ABSTRACT

Interactive-graphic systems and operations research methodologies are increasingly being combined to produce efficient, versatile and powerful tools that enhance the decision making process. We analyze and compare the possible contributions of such tools to the planning of distribution systems for industrial firms and of freight carrier service networks and operations. We derive similarities and differences between the two systems and examine whether a unique planning system may adequately respond to the requirements of the two problems.

Key words : interactive-graphic systems; distribution systems planning; freight transportation systems planning.

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RÉSUMÉ

L'informatique interactive-graphique et la recherche opérationnelle sont de plus en plus utilisées conjointement pour produire des outils d'aide à la décision puissants et souples. Nous analysons et nous comparons les apports possibles de tels outils pour la planification des systèmes de distribution des entreprises industrielles et des réseaux de service et les opérations des entreprises de transport de marchandises. Nous mettons en évidence les similarités et les différences entre ces systèmes et discutons si un outil unique de planification peut apporter une réponse adéquate aux deux types de problèmes de planification.

Mots-clés : systèmes informatiques interactifs-graphiques; planification des systèmes de distribution; planification des systèmes de transport de marchandises.

INTRODUCTION

Over the past few years, interactive-graphic tools have provided the decision maker with powerful means to represent, analyze and plan various industrial systems. They are a definite complement to traditional optimization or simulation techniques for the long, medium or short term planning of such systems.

Interactive-graphic tools help the planner build a meaningful representation of the system. They allow him to define scenarios, examine data and interact with the optimization routines in a friendly, user oriented "language". He is thus able to use his own insight and knowledge of the problems to enhance the solution process and cope with modelling approximations of real situations that cannot be formulated analytically.

A number of interactive-graphic systems have been developed over the past few years for the areas of production, distribution and transportation. They address a variety of specific applications, mostly at the short term, operational planning level, ranging from production scheduling to the routing and scheduling of vehicles. See, for example, Fisher (1986) for a review and classification of these systems. Yet, few interactive-graphic systems have been developed for the modelling and design of longer, tactical or strategic, planning horizon issues such as, facility layout and location, distribution system design, intercity freight transportation service network design and load planning generation, etc.

The logistics system of industrial firms has strong interactions with freight transportation systems at all levels of procurement, production and distribution of goods. The two systems exhibit, therefore, a number of striking similarities and marked differences in their objectives, structures and management of operations.

We are currently involved in the development of various applications in the areas of distribution systems planning and facility location for industrial production or transportation firms, as well as the medium term service network design and the tactical planning of operation for freight transportation firms. We have thus been confronted with the choice of either building a general purpose interactive-graphic system to address all these strategic and tactical planning problems, or of designing several application specific systems, as is the case with systems dedicated to operational planning issues.

The purpose of this paper is to examine and compare the possible contributions of interactive-graphic systems that are based on operations research methodologies, to the planning process of, on one hand, distribution systems for industrial production firms and, on the other hand, of transportation services and operations for intercity freight carrier firms. We aim to identify similarities and differences between two such systems and, in particular, to determine if a unique interactive-graphic system could be appropriate for both types of problems.

To make things precise, we mean by distribution all the logistics operations involved in the management of finished goods from production plants to the final customers, including the physical distribution aspects. These operations can either be performed by the industrial production firm itself or by an independent commercial distribution and sales firm. By freight transportation, we mean the operations performed by one or several carrier(s), using one or several transportation modes, to move freight of various commodities, from multiple clients (cities), between several locations.

In a first part, we review the three stages of the planning process for the distribution activities of the industrial production firm. We then derive the main features of an interactive-graphic modelling system aimed particularly toward strategic and tactical planning. In the following section, we carry the same analysis for intercity freight transportation firms.

A third part is dedicated to the comparison of the two planning processes, of their objectives and specific context. We then derive the common features and specific differences that would characterize corresponding interactive-graphic modelling and planning tools. In our conclusion, we summarize these analyses and discuss the pros and cons of the alternatives of either developing common or specific tools for the planning of distribution and transportation systems.

Due to our own interests and experience, our analysis is more focussed towards the modelling of strategic and tactical planning systems rather than that of short term operational planning or real-time management systems. We believe, however, that our conclusions are general and will contribute to the reflexions in this fast developing area.

1. THE PLANNING PROCESS FOR DISTRIBUTION SYSTEMS

1.1 Structure and planning of distribution systems

Industrial systems are comprised of three interconnected levels: procurement, production and distribution. We will be concerned here only with the distribution system of the firm. We believe, however, that our approach and conclusions may be extended to the other logistics and flow management activities of the industrial system.

The distribution system of the industrial firm serves the combined objectives of storing the manufactured goods after production and transporting them to the final customers according to demand. Transportation is performed at minimum cost, while satisfying specific service and quality requirements such as delivery delays.

While serving its own objectives, the distribution system must contribute to the global optimization of the firm and, in particular, ensure close coordination with its production and sales components.

Distribution systems are organized into a number (commonly two to four) of levels, depending on the economic sector and the specific logistical context:

- The production level (e.g. plants). It is characterized by global and by product throughput capacities, or supplies, and costs (fixed and variable);

- One or more intermediate levels of central and regional distribution centers, warehouses and depots or breakbulk terminals. They mainly serve the purpose of wholesale and retail distribution, storage and order preparation for transportation to the final customer. Their attributes are storage or throughput flow capacities and storage, handling and order preparation costs;

- The customer level, characterized by a demand per product and time period.

These production, storage and customer entities may be viewed as the nodes of a graph, the arcs of which represent transportation capabilities from one entity to the next. Arcs are characterized by flow capacities and costs. They may be duplicated to account for multiple products or transportation modes and time periods.

A distribution system planning model will therefore rely on a mostly hierarchical, multilevel network. Supplies are available at a limited number of origins (production plants), whereas demands are expressed at many destinations (final customers).

Following the general planning process of the industrial firm, the planning process of the distribution system comprises three different stages:

- the strategic planning stage (one to five years):
  - definition of objectives in terms of profit maximization, cost minimization, quality of service;

- long term demand forecasting;
- logistics system design = warehouses and depot location, logistics zone definition and customer allocation to depots;
- resource acquisition (facilities, vehicles);
- distribution policy and coordination with the general planning of the firm;

- the tactical planning stage (one month to one year):
  - distribution network design;
  - transportation mode and capacity choice;
  - monthly planning of storage and distribution;
  - vehicle fleet planning, empty balancing;
  - medium term flow optimization;
  - warehouse workload and inventory policy;

- the operational planning stage (up to one month):
  - in bound transportation from plants to warehouses and depots;
  - inventory management;
  - order preparation;
  - routing and scheduling of distribution tours from depots to clients;
  - empty vehicle management and backhauling.

The last stage of operational planning is the real time management of operations. This, however, is beyond the scope of this paper.

This list of typical operations obviously shows that distribution systems planning include transportation activities. These are either fully managed by the production and distribution firm, or subcontracted to a transportation firm, at least at the short term, operational level. But some of the operations are specific to the distribution firm, such as inventory management, order preparation and coordination with the production sector.

The problem of location and sizing of facilities (e.g. depots) is common to both distribution and transportation firms. It is usually, however, analyzed differently and more frequently by production and distribution firms. It actually is a central issue of distribution systems

planning, addressing such questions as the number of intermediate storage and distribution levels, the number, location and size of warehouses and other facilities, the distribution zone covered by each one of these facilities, as well as the product flow and distribution network optimization. See Geoffrion and Powers (1980) or Dejax (1987) for methodologies concerning facility location.

Note, however, that transportation firms may also have to solve problems of distribution type. In particular, there exists a tendency for transportation firms to offer services that go beyond their primary responsibility and formerly belonged to distribution firms. This is, for example, the case of warehouse and inventory management, order preparation and delivery.

We propose to describe the planning of the distribution system in ten different steps, several of which call for the support of, at least, some of the components of computer based tools, as we will discuss later:

1. Problem definition and objectives.
2. Model formulation.
3. Data collection and analysis.
4. Choice of algorithms or other decision making aids.
5. Model validation, simulation and test on historical data.
6. Solution determination on base case.
7. Sensitivity analysis and alternate scenarios.
8. Scenario evaluations and final decisions.
9. Implementation of decisions.
10. Periodic follow-up and review.

The first five steps correspond to the initial building of the model and are reviewed only once for every strategic planning project, or if major structural changes have occurred. The last five steps are gone through repeatedly as part of the planning process and are reviewed periodically. Of course, these steps are seldom executed in a straight

forward sequence; one has frequently to go back to previous steps for solution refinements.

1.2 Interactive modelling of a distribution system

Interactive modelling is really a way to include the user in the midst of the decision process at all stages of problem formulation and modelling, scenario definition, choice and guidance of algorithm, solution determination and implementation.

The user-system interface works both ways: the interactive-graphic capabilities are a great tool for the user to input data in a visual language that is much closer to his way of thinking that classical batch input. On the output side, the user will be able to comprehend and interpret solutions much more efficiently on a graphical display than through the classical detailed printed computer listing. He can immediately detect errors and react to proposed solutions by confronting them to his own knowledge of the problem. He can also assist the system during the solution process and therefore best utilize his insight of the problem. He can guide the decision software either step by step, or make a sequential use of several different types of decision aids. For example, he can use an optimization algorithm for a first solution approach and refine it with an expert system, for a better conclusion on the qualitative elements. The graphical display of data and solutions also allows the user to more easily cope with aspects of the problem that have been aggregated in the modelling phase, or that where not really quantifiable.

Proper use of the various graphical features of the system (such as colors, windows, zoomings, display of key numerical results, etc.) also supply extremely useful tools to visualize and interpret complex systems and thus better interact with the optimization, simulation or decision software.

Interactive-graphic modelling can allow the user to develop a much better understanding of the problem characteristics and solution process and thus a greater confidence in the decisions. He may be fully involved

in the modelling and decision process by being able to visualize problems and solutions in a close to reality spacial representation, that can even be dynamic in time.

As an example, we can briefly illustrate these concepts by going through the previous modelling steps for the one of the major problems in long term (strategic) distribution systems planning: the location of warehouses. Brady and Rosenthal (1980) and Brady, Rosenthal and Young (1984) propose interactive-graphical models for location problems. Operational planning applications relative to the routing of vehicles may be found in Sorensen (1986).

Step 1 (problem definition and objectives) and Step 2 (model formulation) require preliminary analysis before formulating the problem. Modelling systems such as GANS (Generalized Algebraic Modelling System) (Meeraus, 1986) may be useful for that stage.

Distribution systems planning involves the collection and analysis of large amounts of data of various types. This is done in Step 3. First, the physical data base must be input, once and for all, for a given geographical area. The frontiers of the area under study, as well as geographical coordinates of nodes, origins and destinations of arcs are easily input with interactive tools. Geographical areas may be then visualized and all possibilities of errors verified and, eventually, corrected. Other data, such as demands and costs, are input and verified in a more standard manner, thus completing the constitution of the data base.

Cost functions and demand forecasts are computed and analyzed using a software library for building cost and demand models and estimating parameters.

Step 4 being devoted to the choice of algorithm, or of other decision making tools, it requires user input and experience, depending on the exact nature of the problem.

Steps 5 to 8, dedicated to model validation and scenario definition and evaluation, provide opportunities for a thorough user involvement into the decision process, through the appropriate use of the interactive-graphic capabilities of the system.

As an example, a given scenario may specify the candidate locations to consider for warehousing, as well as the customer demand, plant capacity and cost parameters. A visual representation of the scenario is useful and particularly that of the corresponding network. Once the user is satisfied with the scenario definition, the chosen algorithm may be run. The results are displayed with a geographical representation of the chosen warehouses, flows from plants to warehouses and clients and logistic zones borders. The information part of the screen displays key solution information such as costs, flows, and capacities. While analyzing the results presented to him in such a convenient way, the user may incorporate qualitative factors in his judgement and define another scenario to study, for final decision in Step 8.

Steps 9 and 10 may require less creative use of the computer. It is needed, however, to produce plans and results that are necessary for decision implementation and review.

1.3 Architecture of an interactive modelling system

Interactive and visual modelling of a distribution system may thus greatly enhance the decision process, even if operations research methodologies were already used. Beyond providing easy and attractive communication interfaces, it also offers the capability to evaluate the qualitative aspects of solutions and to detect obvious errors and modelling weaknesses. One may then better cope with problem aspects that are difficult to quantify and achieve better insights of the solution process and increased confidence in the results.

Such a system will comprise the three now classical components: a methodological core, a data base and interactive-graphic capabilities. We address these main features below.

The methodological core of a distribution system planning model focussed on strategic and tactical issues will primarily consist of one of the many existing variants of a warehouse location model. See Tansel et al. (1982) or Krarup and Pruzan (1983) for surveys of some of these models. The appropriate model and algorithm will be highly dependent upon the particular distribution system under study. Also depending on the particular problem, the location model could be supplemented by additional models, focussed upon specific issues such as flow optimization, inventory management or the routing of vehicles. Combined models are also available (Geoffrion and Graves, 1974; Laporte, 1987).

In any case, the main component of a methodological core, focussed on warehouse location issues for distribution systems planning, will generally be a model and algorithm of combinatorial nature, even if other types of models (such as those using simulation techniques or continuous approximations (Daganzo and Newell, 1986), for example) are also available. Expert systems will certainly also be of interest in the future. In addition, the methodological core may contain classical statistical analysis routines for parameter estimation.

The data base comprises the following components:

- The base "physical" network: for a given geographical area (e.g. a specific country), it forms the permanent graph specifying the grid of possible locations and transportation arcs with their characteristics (names, capacities, distances or travel time parameters, etc.);
- The "conceptual" network: it is the model representation of the distribution system under study. Nodes correspond to the existing locations of industrial facilities and customers, and to the complete list of

candidate locations in the case of a facility location problem. Multi-product, multimode arcs link two nodes if a freight shipment may be made from the origin to the destination node. Parameters associated to the nodes and arcs are either input directly by the user or extracted from the physical network. For example, distance or travel times between nodes of the conceptual network may be computed by using a shortest path algorithm, present in the software library, between the corresponding nodes of the physical network;

- A supply, demand and flow data base. For a given company, it is constructed from historical files or forecasts. Supplies and demands are to be associated with the corresponding nodes of the logical network, while flows are associated to arcs. These components serve either for optimization or simulation purposes and for model validation;

- A cost analysis data base. It consists of cost formulae that will be used for evaluation of cost parameters. The cost formulae may be either exogeneously input or determined by applying statistical analysis routines from the software library. The cost parameters, once estimated, are associated with the relevant components of the nodes and arcs of the conceptual network.

Interactive-graphic capabilities benefit greatly from the continuous and fast progress of computer hardware and software technology. They allow an easy, "user-friendly", input and visual representation of data, which facilitates the fruitful involvement of the user in the planning process through a modular and menu driven system architecture. Fisher (1986) extensively discusses the contribution of interactive optimization and graphical procedures to logistics problems.

A specialized interactive-graphic system for distribution systems planning will make an extensive use of basic graphic software capabilities, adapted to the specific requirements of this kind of application and its

underlying network structure. For each scenario, the main graphic request will concern the global display of the logistic zones under study, including the location of production plants, potential or chosen warehouse locations and territory, customers or customer zones, links and product flows between these locations, etc. Additional, specific displays of geographical zones or subsystems, such as the detailed procurement or distribution links of a given warehouse, are also required. The system has to facilitate the display of synthetic information relative to each scenario, as well as easy procedures for the construction of alternate scenarios. In particular, besides the usual demand and cost parameters which are subject to sensitivity analysis, scenarios are characterized by the lists of candidate warehouse locations to be kept open, closed or left free, to the discretion of the optimization routine (Dejax, 1987).

2. INTERCITY TRANSPORTATION SYSTEMS

Freight transportation is one of today's most important economic activities. Fierce intra and inter modal competition is observed among carriers, while the expansion of containerization and intermodal transportation combined with a general trend toward the deregulation of the industry, forces them to rapidly adjust the operating policies to new environments.

Freight carriers have to be economically efficient, operationally flexible and offer reliable and high quality services. The constant improvement of the methods and tools used to plan the development and utilization of a carrier's transportation system is one of the main ways to achieve these objectives.

2.1 Structure of a freight transportation system

The various elements that have to be considered when planning the operations of an interurban freight transportation system may be classified

into one of the three following categories: physical network (infrastructure), service network and freight traffic.

The basic structure of any large freight transportation system consists of a complex network of large classification-consolidation terminals, relatively small stations where pick-ups and deliveries may be made and junction points, all connected by physical (e.g. rail) or conceptual (e.g. truck or sea) links.

On this physical network, transportation services are usually performed by a large number of vehicles which carry the freight between points (origin-destination pairs) of the network. Vehicles move either individually or grouped in convoys such as trains, multi-trailer assemblies, etc. Each service is characterized by a physical route and, eventually, by the sequence of terminals where it stops on this route. From an operational point of view, each service is described by its transportation mode, which defines its vehicle characteristics (convoy length, speed, priority, operating and delay costs, etc.) and by its frequency, which specifies the level of service (the number of times the service is operated) during the planning period. When some services are captive of the infrastructure, such as trains in rail transportation, one then observes congestion phenomena on the links of the network that increase travel times.

Freight is usually differentiated by class of commodity, according to physical characteristics, or value, or both. Transportation demand is then generally specified by market (origin-destination-commodity) and is expressed in terms of a certain measure of freight tonnage, or number of vehicles, of the given commodity to be moved from the origin terminal to the destination terminal. In an integrated intercity freight transportation system, freight is rarely moved on an individual basis, but rather it is consolidated into more or less aggregated formations: vehicles, blocks,

trains, multi-trailer assemblies, etc. A simple physical path is then insufficient to describe how the traffic of a particular market moves through the transportation network and itineraries have to be used instead. Each itinerary corresponds to a feasible journey for the traffic of a given market and is defined both by a physical and a service route. Conceptually then, an itinerary may be described as a sequence of terminals where consolidation-classification operations are performed on the traffic moving along and by the services used to move between two consecutive terminals of that sequence. Several itineraries may be used concurrently to transport freight from the same market.

This policy of successive aggregations of freight and freight vehicles into larger formations has a dual impact on the transportation system and its planning. On one hand, the profitability of the whole system is increased due to the economies of scale that can be achieved on the long-haul movements. On the other hand, it also significatnly increases the type, number and complexity of terminal operations, as well as the corresponding terminal congestion and delays, thus greatly contributing to the complexity of the planning process of the system in general and of terminal operations in particular.

Note also that, imbalances in the spatial distribution of demand are usually present in the system, generating an imbalance in the supply and demand of empty vehicles at the nodes of the network (Dejax and Crainic, 1987). Empty balancing procedures have then to be called upon to alleviate this problem.

2.2 Tactical planning

To control these activities and make the best possible use of the system's resources, several policies have to be defined and implemented. These policies are generally classified in the three same planning levels described earlier for the planning of distribution systems:

a) strategic planning, where capital investments for resource acquisition, general development policies and broad operating strategies for the system are decided upon. Prime examples of decisions at this planning level are:

- physical network design and upgrading;
- facility (terminals, etc.) location;
- resource (rolling stock) acquisition, etc.;

b) tactical planning aims to insure, over a medium term horizon, an efficient and rational allocation of existing resources to improve the performance of the whole system. Tactical decisions need to be made concerning the following issues:

- service network design: the services used and their frequencies;
- traffic distribution for each market;
- terminal policies;

c) operational (short term) planning is performed by local management in a highly dynamic environment where the time factor and detailed representations of the various system components are essential. Operational level decisions are mainly concerned with the scheduling of services, crews, maintenance activities, etc. and the allocation of local resources (vehicles, trucks, priorities, etc.). The development of real-time computer based systems for the planning of these policies are beyond the scope of this paper.

Strategic planning issues in freight transportation are related to similar problems in industrial firms, specifically in distribution systems, and thus the discussion of the previous section is also valid here.

Tactical planning, on the other hand, usually appears as a vital link in the planning process of freight transportation systems (Crainic, 1987; Roy, 1985). Its output consists of a series of rules and policies that affect the whole system and that often are collected in a transportation (load) plan. These rules and plan are then used to determine the

day-to-day policies that guide the operations of the system. The same tactical transportation plan is also a privileged evaluation tool for "what-if" questions raised during strategic planning.

The generation of a good transportation plan generally is, however, a difficult task. Not only each of its three major components (service design, freight distribution, terminal policies) corresponds to a complex, large scale problem which affects the network-wide performance of the system, but the strategies developed for one problem also interact with, influence, and are influenced in a most complex way by those established for the other problems. Trade-offs have also to be realized between operating costs and some measure of quality and reliability of service, usually expressed in terms either of delays imposed on freight and carriers or of performance targets. These trade-offs are important when a single problem and decision is considered and even more so when the relationships among decisions aimed at different problems are contemplated. Therefore, decisions have to be made globally, network-wide, in an integrated manner. Besides, the problem has a great number of equivalent solutions, in the sense that different configurations and levels of service, combined with the corresponding freight distribution, may generate approximatively the same total operating and service cost. Sensitivity analyses and additional discriminating criteria (other than the usual time-cost ones) have then to be used, and these criteria are quite difficult to integrate into classical economic or operations research formulations.

The tactical planning process of freight transportation systems thus reflects their complexities and has an important component of scenario evaluation. Accurate, efficient and flexible tools are therefore needed to help the planner in his task. In this context, a combination of operations research models and computer science techniques may be of considerable help by supplying tools to facilitate and enhance the planning activities (Crainic and Roy, 1988).

2.3 Architecture of a planning tool

The considerations and characteristics developed above play an important role in defining the requirements of a comprehensive planning system for the tactical planning of multimode multicommodity intercity freight transportation systems (Crainic and Mondou, 1986; Crainic and Roy, 1988). Particularly, it should allow to

a) address the problem globally, network-wide, integrating the main aspects of tactical decisions and their interrelationships;

b) efficiently generate and evaluate a large number of different operating strategies to select the most promising for a tactical plan or a strategic scenario;

c) conveniently access, treat and display a very large quantity of information when preparing scenarios or analyzing data and results;

d) facilitate the interaction between the system and the planner.

The system is then made up of, the now classical, three components: the methodological core, a data bank and the interactive-graphic interface.

The methodological core contains the operations research models and algorithms necessary to generate, evaluate and select operating strategies and transportation plans, to do postoptimal analyses, etc. Both models and algorithms should be flexible and robust to accomodate various model representations of the components of the transportation system (terminals, stations, links, ...) and of the operations performed therein, especially for scenario definition and evaluation. The system should also permit the modular use of the various models and procedures to analyze individual components (such as the frequency of a given service or some traffic distribution) or parameters (e.g. operating or delay costs, capacities, etc.) of the transportation system.

The system has to be interactive-graphic, for increased efficiency and user-friendliness. More specifically, interactive-graphic capabilities would enhance the planner-system relations and facilitate the creation and evaluation of scenarios, the selection of an operating strategy among several different solutions with essentially the same objective value, the manipulation of a chosen solution until it respects all the unwritten or unprogrammable rules, etc. This would also help manage and apprehend the huge quantity of information present in the data bank.

From a structural point of view, the system could be built following rules that have proved very efficient for other successful planning tools for systems of similar complexity, such as urban passenger planning (Babin et al., 1982) or national stragegic planning (Florian et al., 1987). The system is organized following a modular structure. Each module is an independent program that addresses a specific task. There is no hierarchy and no direct communications among modules, each one taking its data from and returning its results to the data bank. The system, and all modules, are menu driven, the main menu also being a module. Such an organization has multiple advantages: increased flexibility to build, maintain and modify the system, a decrease of the system size, increased response speed, etc.

The planning system would accept inputs either in batch files or interactively. It would output results in batch files or as images that could either be displayed directly on the screen or be presented as plot files that could go to the printer, plotter or any other printing or storing device. Graphical modules should be available to interactively request and display informations present in the data bank, and also to interactively modify its contents, especially the network defining data. That capability is most essential to an efficient scenario definition. Graphically speaking, the system should be able to take into account the successive layers of information present in a freight transportation

system: the physical network, the service structure and the commodity flows. Also several multi-valued attributes (e.g. number of vehicles, of convoys, of tons per mode, market, commodity class) have to be jointly displayed on the same element (e.g. physical link).

The data bank contains: physical networks, service networks, matrices (including the O-D demand), functions (including cost and delay functions for terminals and links), commodity path flows for all markets and auxiliary data including demarcations, statistics, etc. Thus, data pertaining to the planning of intercity freight transportation systems is both abundant and complex. The size and complexity of the bank are further increased due to the necessity to explicitly consider path information for commodity flows and service routes and to the data multiplication corresponding to the various hypothesis (scenarios) concerning the state of the transportation system: infrastructure, service network design, level and composition of demand, etc. The data bank should therefore be structured to accomodate these requirements, to reflect the hierarchical relations that exist between the various data elements, to ease the control of its size and to facilitate its exploration and modification, and to efficiently support the optimization and graphic procedures.

The requirements of the tactical planning process and the structural needs of the planning system and of the underlying data bank may be more easily met if a "by scenario" functioning principle is adopted for the planning tool.

A "scenario" corresponds to a possible configuration of the transportation system (physical and service networks, specification of the demand and functions to be used, etc.) and may contain results. By using scenarios, links are established between the various data elements and results of the data bank. It also helps control the evolution of the size of the bank, as well as the quantity of information available at each working session. Figure 1 illustrates the conceptual utilization of a planning system created according to these principles.

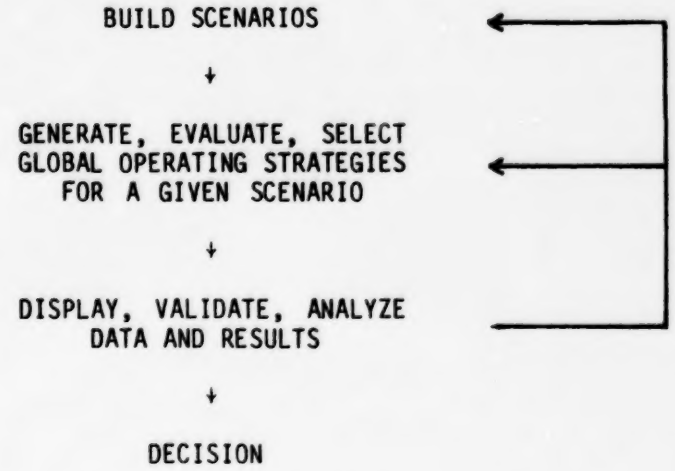

Figure 1: Planning process using an interactive system

3. DISCUSSION

In the preceding sections, we have described the planning processes of the distribution system of an industrial firm and of the service network and operations of a transportation firm. We have shown how interactive-graphic capabilities could be used for a full involvement of the planner in the modelling and solution activities. Yet, a computer system, although sophisticated, is only a tool intended to help the decision maker in the planning process. Therefore, to address the question of whether similar interactive planning systems could be used for both distribution and transportation systems planning, one must first compare the operations involved in these planning processes as described above.

Figure 2 summarizes the planning operations of both distribution and transportation systems for the strategic, tactical and operational levels. A number of these operations are common to both systems (for example the routing and scheduling of vehicles and crews); others are specific to one or the other system (such as coordination with production planning for the distribution system or the physical network design for transportation

	Distribution Systems	Transportation Systems
Strategic (long term) Planning)	• Definition of objectives • Demand forecasting • Logistics system decisions: facility location and logistics zones • Resource acquisition (facilities, vehicles ...)	
	• Distribution policy • Coordination with general planning of firm (production ...)	• Transportation policy • Physical network design
Tactical (medium term) Planning	• Service network design • Capacity choice • Vehicle fleet planning, Empty balancing	
	• Coordination with sales and production • Flow optimization • Warehouse workload management, inventory	• Traffic distribution • Terminal policies: consolidation, classification
Operational (short term) Planning	• Crew scheduling • Vehicle routing and scheduling • Empty vehicle backhauling • Customer order preparation • Real-time dispatching	
	• In-bound warehouse procurements • Warehouse management • Inventory • Final distribution	• Terminal facility management • Transportation

Figure 2: Planning issues in distribution and transportation systems

systems; while a third group (such as the optimization of flows and the management of terminals), although specific to a system are paralleled by similar issues in the other system's context. We must also remark that some common operations may be performed by both types of planners, but each with a different perspective. For example, warehouses have different objectives in an industrial distribution system (collection, storage and distribution to the final customers of commodities produced by the plants) from those of terminals, freight breakbulk or vehicle classification terminals, in a transportation firm (collection from and transportation to many clients of commodities produced outside the company's system). We discussed earlier the fact that warehouse location is a central issue in distribution systems planning, while network design is one in transportation systems planning at the strategic and tactical levels.

Thus, while the planning processes of distribution and transportation firms obviously show many similarities, there are differences due to their basic nature: the storage and distribution of goods output from the production system of the firm on one hand, the collection, transportation of commodities from many clients to many other clients on the other hand.

These differences are directly reflected in the models and algorithms that are used to solve the respective planning problems. Interactive planning systems would have to reflect these differences and several sets of models and algorithms have to be included if only one system has to be designed. This, may not be very efficient, however, since different models and algorithms have different requests on the contents and organization of the data bank.

Let us now compare the modelling issues associated to (see Figure 3) and the main characteristics of the three components (methodological core, data base, interactive-graphic capabilities) of an interactive-graphic modelling system (see Figure 4) for distribution and transportation firms. One may remark that many different features characterize both problems. The

	Distribution Systems	Transportation Systems
System structure	Simple/Multiechelon	Network
Product flows	Single/Multicommodity	
Transport modes	Single/Multimode	
Fleet type	Homogeneous/Heterogeneous	
Zone	Urban/Intercity	
Modelling issues	• Capacitated/Uncapacitated • Linear/Nonlinear costs • Deterministic/Stochastic demands, supplies, travel and terminal times, etc.	

Figure 3: Modelling issues for distribution and transportation systems

	Distribution Systems	Transportation Systems
Methodological Core	• Distribution planning models: - facility location - flow optimization - inventory management	• Transportation planning models: - network design - network optimization - flow optimization
Data base	INPUT • Geographical network: locations (cities), arcs, distances • Conceptual network: nodes: plants, warehouses, customer zones arcs : links	• Physical network nodes: terminals arcs : links • Service network nodes: terminals arcs : transportation services
	• Supply/demand matrices • Cost models and parameters	
Interactive-graphic capabilities	BASIC STRUCTURE • Modular structure • Works on scenarios • Input : - batch files - interactively • Output: - batch files - video display - printer, plotter	
	SPECIFIC REQUIREMENTS	
	• Displays of global system: - locations - zones • Specific displays: - in/out of nodes (plant, warehouse, customer zone) • Rather synthetic information	• Successive layers of informations: - physical network - service network - commodity flows • Many attributes to be displayed jointly on same elements: - vehicles - node - convoys per - traffic class - tons - commodity

Figure 4: Characteristics of interactive-graphic systems for distribution/transportation systems planning

basic modelling characteristics are mainly the same, a particular choice being dictated more by the size and complexity of the operations of the particular firm than by its nature (distribution or transportation). Yet, the resulting operations research models and algorithms are significantly different in nature and complexity. Thus, distribution systems problems often include combinatorial, facility location type of models, where transportation issues are rather represented as nonlinear multicommodity flow optimization models.

The differences in the contents of the data base are not significant enough to preclude that a similar organization and functioning principle be adopted for the two planning tools, in general, and the data base, in particular. We must remark, however, that the visual representation which would be convenient for each type of firm may differ significantly due to the different structure and system utilization. As an example, the distribution system of an industrial firm is often visualized as a hierarchical, multilevel network, showing production, warehousing and client levels. The network representation of a transportation firm will usually be much more general in design and involve a larger number of information layers on this network. Yet, the network structure underlying both systems allows a unique set of graphical procedures and display principles (Mondou, Couture and Crainic, 1988) to be used to represent the layout and operations of these two different types of firms.

CONCLUSION

From this discussion it evidently appears that interactive-graphic modelling can greatly enhance the planning process for both distribution and transportation systems at the strategic and tactical levels. Distribution and transportation systems have a number of common characteristics but also bear significant differences in their objectives and requirements, as

well as in their constraints. Thus, one observes a tendency for some industrial production firms to subcontract part of their distribution activities to independent distribution or transportation firms. Similarly, some transportation firms, especially in the trucking area, show willingness to undertake commercial distribution activities for their shippers. Even in these cases, however, the differences between their objectives and long-medium term planning issues remain important when distribution and transportation systems are considered.

These differences call for operations research methodologies that, despite some common features, differ significantly in key characteristics and complexity. Also, in spite of a common network structure, the elements to be stored in the data base and graphically displayed present rather important differences.

Common interactive-graphic systems could be developed for the planning of distribution as well as transportation systems. However, we believe that the differences highlined above would lead to systems that would, either not be sufficiently adequate and performant for either type of problem, or technically inefficient and cumbersome to use.

A better direction seems to be in the development of different, specialized planning systems based on a number of common basic procedures, standards and functional principles. The systems would thus be designed to make the best use of common features and aim for the highest technical and data compatibility and complementarity. This would increase their efficiency and usefulness especially when both distribution and transportation activities are performed by the same firm.

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